CLAIMS

What is claimed is:

1. A method for imaging the spatial distribution and concentration level of macular carotenoids, the method comprising:

obtaining a light source that generates light at a wavelength that produces a Raman response with a wavelength shift for one or more macular carotenoids to be detected;

directing light from the light source onto macular tissue of an eye for which macular carotenoid levels are to be measured;

collecting light scattered from the macular tissue, the scattered light including elastically and inelastically scattered light, the inelastically scattered light having a plurality of Raman signals corresponding to the one or more macular carotenoids;

selectively removing the elastically scattered light;

analyzing the spatial position and intensity of the Raman signals in the inelastically scattered light; and

producing an image of the Raman signals, the image representing the spatial distribution and concentration level of the one or more macular carotenoids in the macular tissue.

2. The method of claim 1, wherein the light source generates light at a wavelength that overlaps the absorption bands of the one or more macular carotenoids to be detected.

3. The method of claim 1, wherein the light source generates light in a wavelength range from about 350 nm to about 550 nm.

4. The method of claim 1, wherein the light from the light source has an intensity that does not destroy the macular tissue and does not substantially alter carotenoid levels in the macular tissue.

5. The method of claim 1, wherein the light source generates light at an exposure spot size of about 5 microns to about 10 mm.

6. The method of claim 1, wherein the light source generates light with an exposure time of about 0.001 to about 100 seconds.

7. The method of claim 1, wherein the macular tissue resides in a live subject.

8. The method of claim 1, wherein the inelastically scattered light is analyzed at frequencies characteristic of macular carotenoids.

9. The method of claim 1, wherein the image of the Raman signals is an en face map.

10. The method of claim 1, wherein the image of the Raman signals is a topographical surface plot.

11. A method for imaging the spatial distribution and concentration level of carotenoids in biological tissue, the method comprising:

obtaining a light source that generates light at a wavelength that produces a Raman response with a wavelength shift for one or more carotenoids to be detected;

directing light from the light source onto biological tissue for which carotenoid levels are to be measured;

collecting light scattered from the biological tissue, the scattered light including elastically and inelastically scattered light, the inelastically scattered light having a plurality of Raman signals corresponding to the one or more carotenoids;

selectively removing the elastically scattered light;

analyzing the spatial position and intensity of the Raman signals in the inelastically scattered light; and

producing an image of the Raman signals, the image representing the spatial distribution and concentration level of the one or more carotenoids in the biological tissue.

12. A method for imaging the spatial distribution and concentration level of selected materials in retinal tissue, the method comprising:

obtaining a light source that generates light at a wavelength that produces a Raman response with a wavelength shift for a material to be detected;

directing light from the light source onto retinal tissue of an eye for which levels of the material are to be measured;

collecting light scattered from the retinal tissue, the scattered light including elastically and inelastically scattered light, the inelastically scattered light having a plurality of Raman signals corresponding the material;

selectively removing the elastically scattered light;

analyzing the spatial position and intensity of the Raman signals in the inelastically scattered light; and

producing an image of the Raman signals, the image representing the spatial distribution and concentration level of the material in the retinal tissue.

13. An imaging apparatus, comprising:

a light source that generates light at a wavelength giving a Raman response with a wavelength shift for one or more carotenoids to be detected;

a light delivery and collection means in optical communication with the light source for directing light onto tissue and collecting scattered light from the tissue;

wavelength selective means for selecting Raman shifted light from collected scattered light;

detection means for measuring the intensity of the Raman shifted light at frequencies characteristic of the one or more carotenoids to be detected;

analyzing means for determining the spatial position and intensity of Raman signals in the Raman shifted light; and

output means for producing an image of the Raman signals, the image representing the spatial distribution and concentration level of the one or more carotenoids.

14. The imaging apparatus of claim 13, wherein the light source generates light at a wavelength that overlaps the absorption bands of the one or more carotenoids to be detected.

15. The imaging apparatus of claim 13, wherein the light source generates light in a wavelength range from about 350 nm to about 550 nm.

16. The imaging apparatus of claim 13, wherein the light source generates light at an exposure spot size of about 5 microns to about 10 mm.

17. The imaging apparatus of claim 13, wherein the light source generates light with an exposure time of about 0.001 to about 100 seconds.

18. The imaging apparatus of claim 13, wherein the wavelength selective means is adapted to be angle tuned to alternately transmit Raman shifted light at an on peak wavelength position, or to transmit light at an off peak wavelength position.

19. The imaging apparatus of claim 13, wherein the wavelength selective means is adapted to simultaneously transmit Raman shifted light at an on peak wavelength position and to transmit light at an off peak wavelength position.

20. The imaging apparatus of claim 13, wherein the detection means comprises an optical detector array on a charge coupled device camera.

21. The imaging apparatus of claim 13, wherein the detection means comprises a discrete photo detector.

22. The imaging apparatus of claim 13, wherein the analyzing means comprises a computer.

23. The imaging apparatus of claim 13, wherein the output means comprises a visual display monitor.

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24. The imaging apparatus of claim 13, wherein the output means comprises a printer.

25. The imaging apparatus of claim 13, wherein the image produced by the output means is an en face map.

26. The imaging apparatus of claim 13, wherein the image produced by the output means is a topographical surface plot.

27. An imaging apparatus, comprising:

a light source that generates light at a wavelength giving a Raman response with a wavelength shift for one or more carotenoids to be detected;

an optical module in optical communication with the light source, the optical module configured to direct light onto tissue and collect scattered light from the tissue;

one or more wavelength selective devices configured to select and transmit Raman shifted light from collected scattered light;

an optical detection device configured to measure the intensity of Raman shifted light at frequencies characteristic of the one or more carotenoids to be detected;

a data processing device operatively connected to the optical detection device, the data processing device adapted to determine the spatial position and intensity of Raman signals in the Raman shifted light; and

an output device adapted to display an image of the Raman signals, the image representing the spatial distribution and concentration level of the one or more carotenoids.

28. The imaging apparatus of claim 27, wherein the light source comprises a mercury arc lamp.

29. The imaging apparatus of claim 27, wherein the light source comprises an argon ion laser.

30. The imaging apparatus of claim 27, wherein the light source generates light in a wavelength range from about 350 nm to about 550 nm.

31. The imaging apparatus of claim 27, wherein the optical communication between the light source and the optical module is provided by a fiber optic bundle.

32. The imaging apparatus of claim 27, wherein the optical module comprises:

a collimating condenser lens;

a band pass filter in optical communication with the condenser lens; and

a dichroic or holographic beam splitter in optical communication with the band pass filter.

33. The imaging apparatus of claim 32, wherein the optical module further comprises a lens in optical communication with the beam splitter and configured to focus light onto the tissue and collect light scattered back from the tissue.

34. The imaging apparatus of claim 32, wherein the optical module further comprises a scanning-type instrument in optical communication with the beam splitter and configured to sequentially scan a light beam from point to point across the tissue.

35. The imaging apparatus of claim 27, wherein the one or more wavelength selective devices comprise a narrow band interference filter and a broad band interference filter.

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36. The imaging apparatus of claim 35, wherein the narrow band interference filter is adapted to be angle tuned.

37. The imaging apparatus of claim 27, wherein the one or more wavelength selective devices comprise a fully blocked narrow band filter.

38. The imaging apparatus of claim 27, wherein the one or more wavelength selective devices are selected from the group consisting of acousto-optic tunable filters, and dispersion based devices.

39. The imaging apparatus of claim 27, wherein the optical detection device comprises an optical detector array on a charge coupled device camera.

40. The imaging apparatus of claim 27, wherein the optical detection device comprises a discrete photo detector.

41. The imaging apparatus of claim 40, wherein the discrete photo detector is selected from the group consisting of a photomultiplier tube, and an avalanche photo diode.

42. The imaging apparatus of claim 40, further comprising a pinhole aperture disposed in front of the discrete photo detector.

43. The imaging apparatus of claim 27, wherein the data processing device comprises a computer.

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44. The imaging apparatus of claim 27, wherein the output device comprises a visual display monitor.

45. The imaging apparatus of claim 27, wherein the output device comprises a printer.

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